(12) UK Patent Application (19) GB (11) 2 124 943 A

(21) Application No **8316145**
(22) Date of filing **14 Jun 1983**
(30) Priority data
(31) **8210657**
(32) **18 Jun 1982**
(33) **France (FR)**
(43) Application published
29 Feb 1984
(51) INT CL^3
B24B 13/04
(52) Domestic classification
B3D 1D3D 1H9A 2A13 2A15 2A20 2A5 2A9
(56) Documents cited
None
(58) Field of search
B3D

(71) Applicants
Essilor International, (France), 1 Rue Thomas Edison, Echat 902, 94028 Creteil Cedex, France.
(72) Inventors
Alain Morel, Bruno Fadalti.
(74) Agent and/or Address for Service
Withers & Rogers, 4 Dyer's Buildings, Holborn, London EC1N 2JT.

(54) **Machining curved surfaces**

(57) A machine for machining curved surfaces, in particular surfaces of optical lenses 42 having a toric or aspherical revolution shape, comprises in a housing a first support 35 of a rotating cutting tool 38.

The support 35 is fixed to a second support 25 driven in rotation about an axis 55 borne by a third support 18 adapted to be displaced along two orthogonal axes, movement about the axis 55 and along the orthogonal axes being under numerical or digital control.

The lens 42 to be ground is mounted on a head 44 so as to be movable between loading 59 and grinding positive.

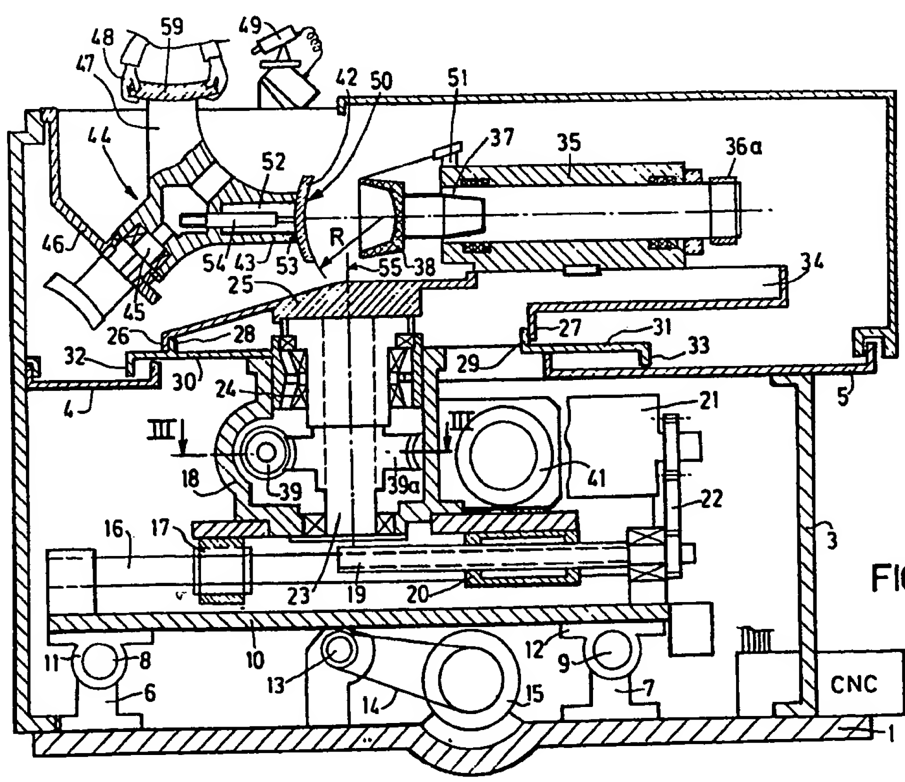

FIG.1

GB 2 124 943 A

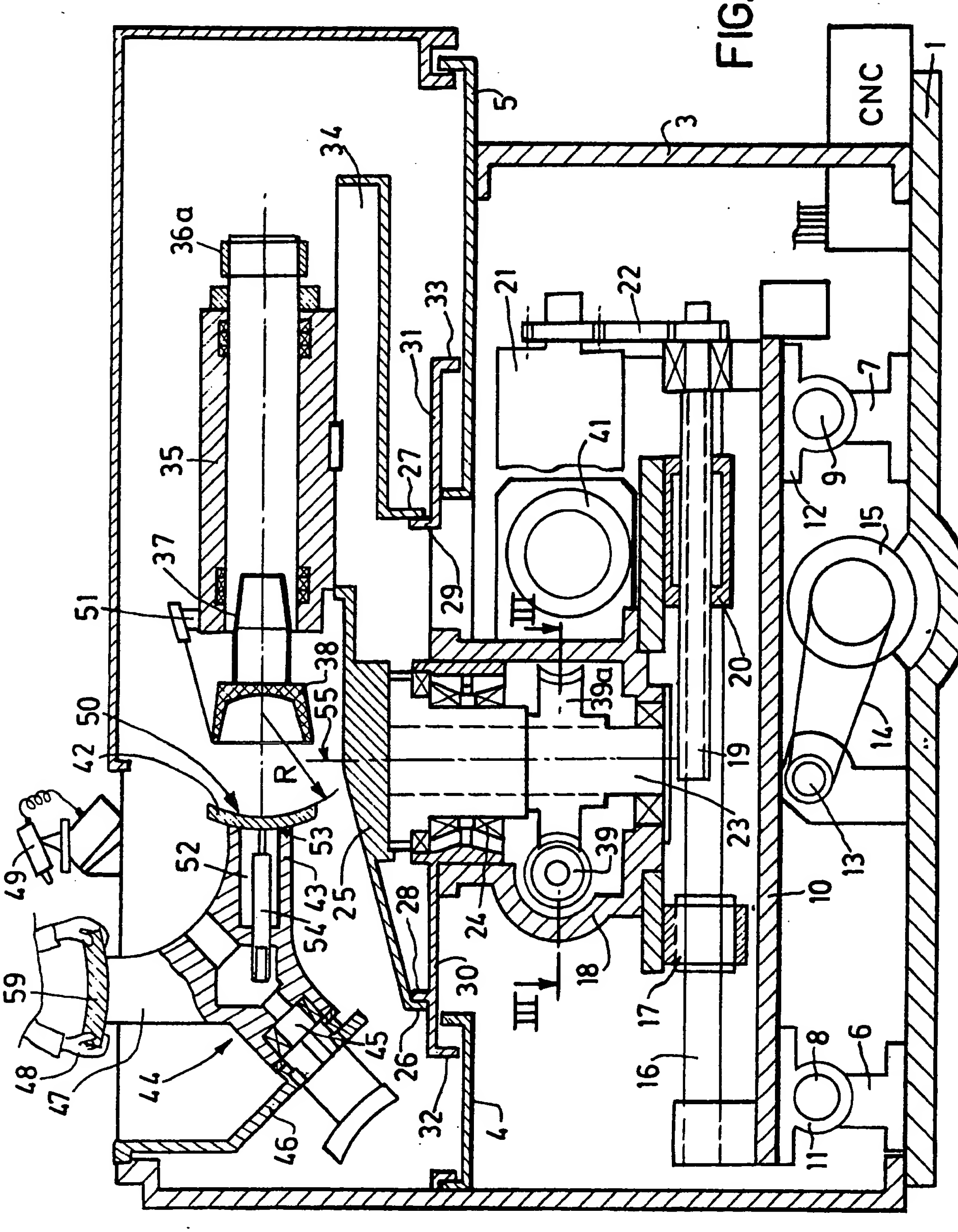
CNC
R
1
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36a
37
38
39
39a
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
59
III
III

FIG.1

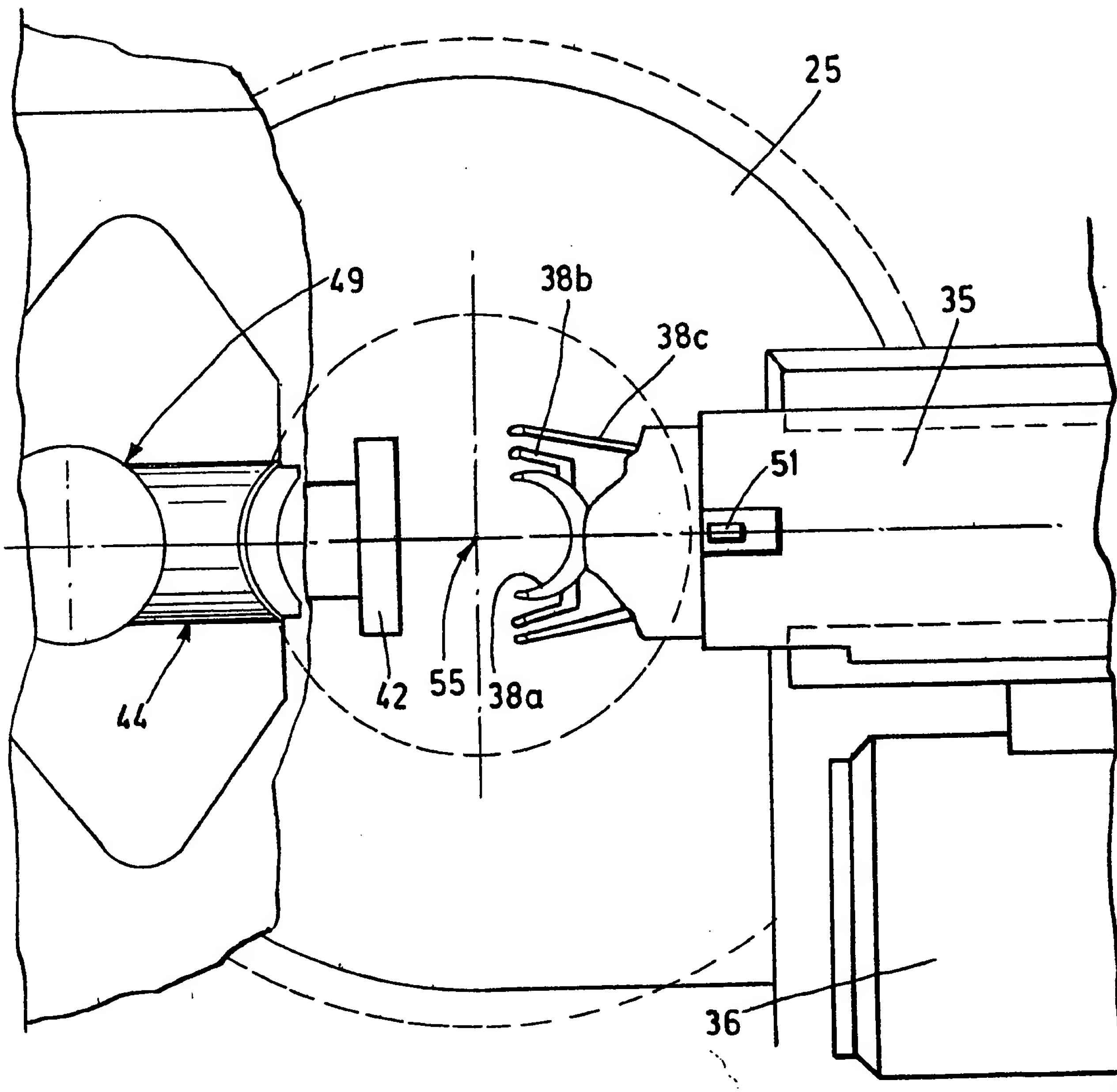

FIG.2

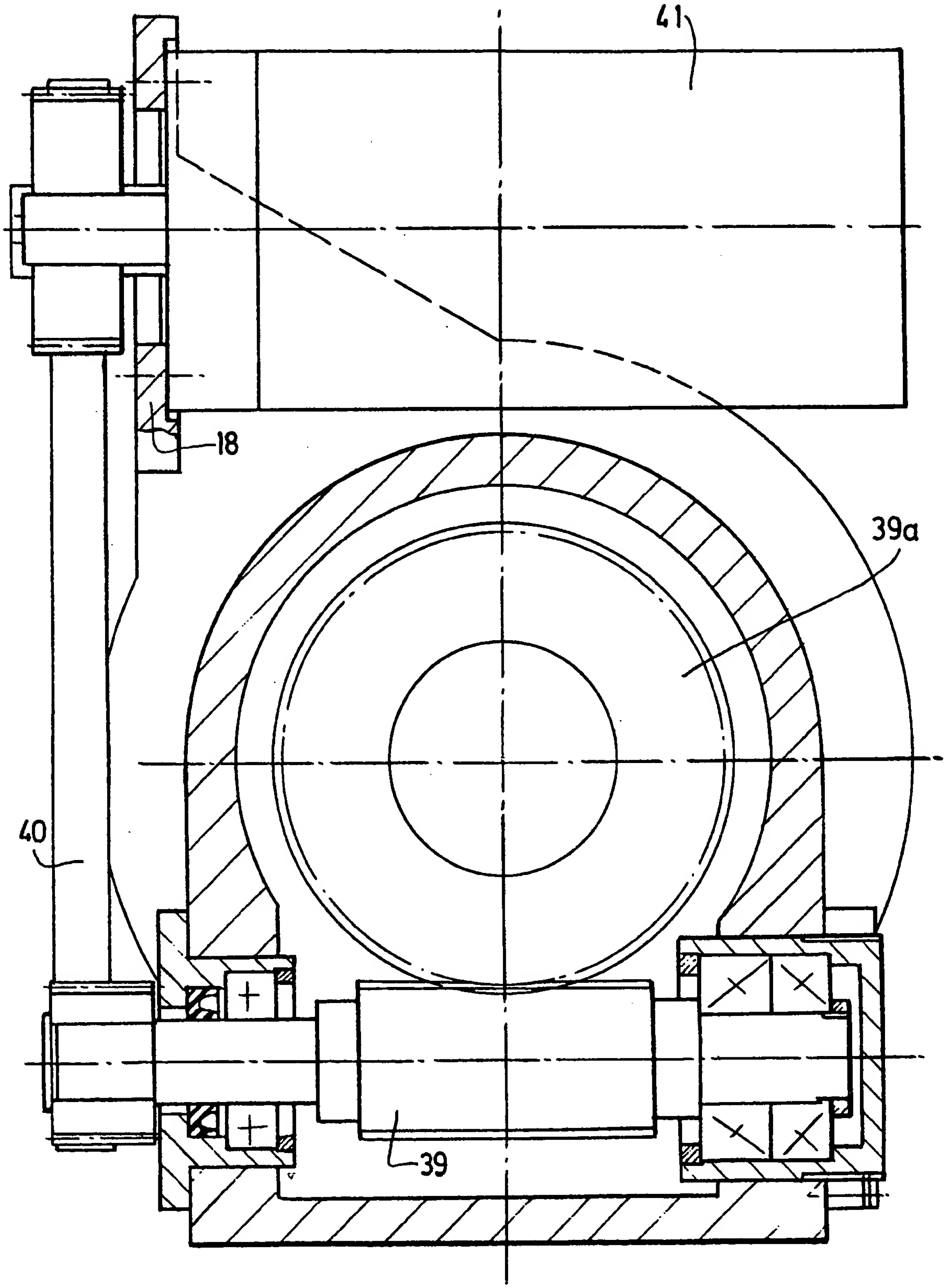

FIG.3

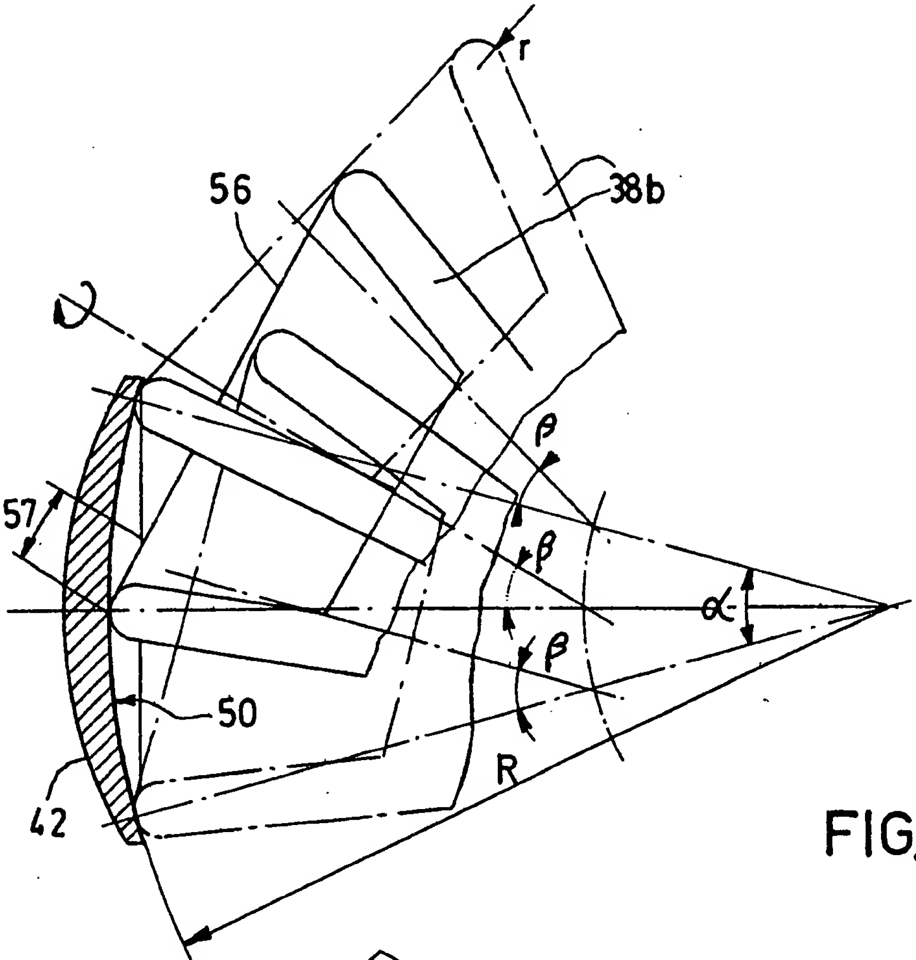

FIG.4

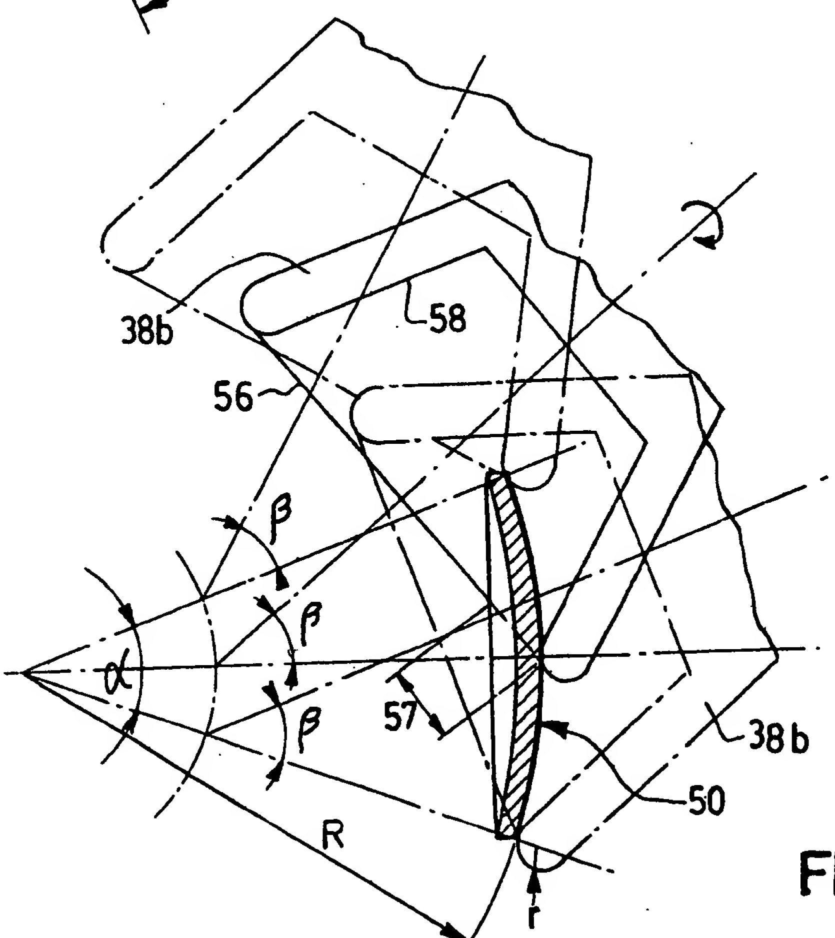

FIG.5

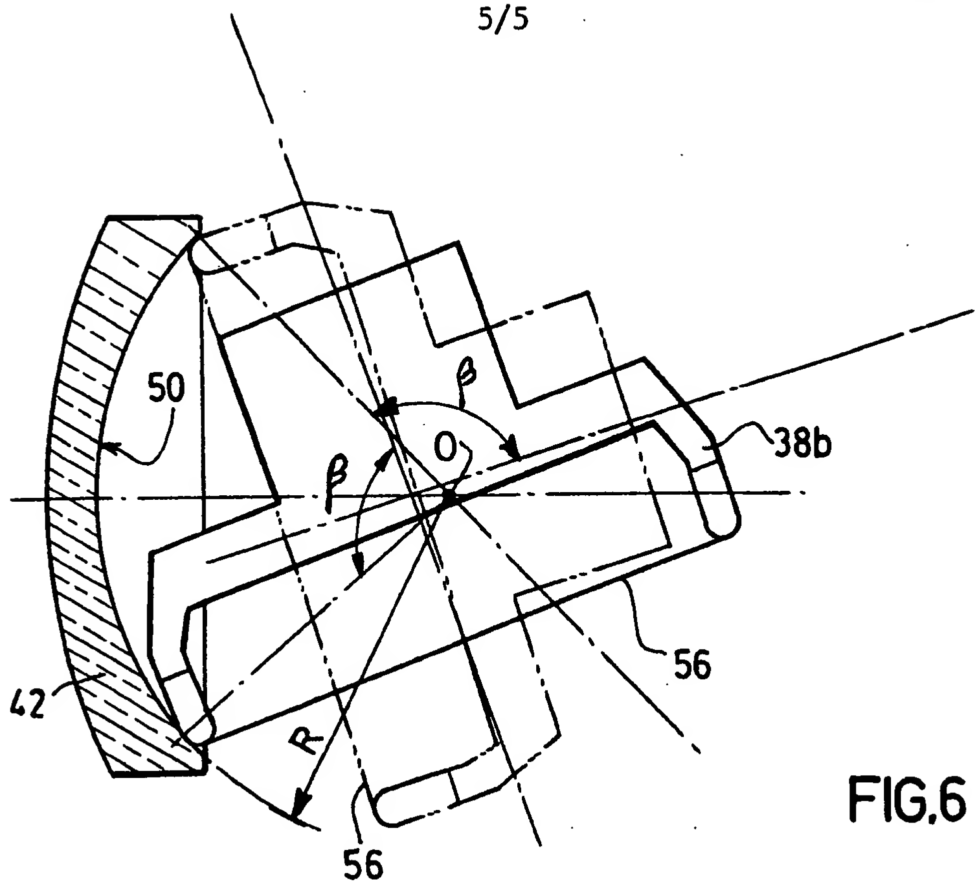

FIG.6

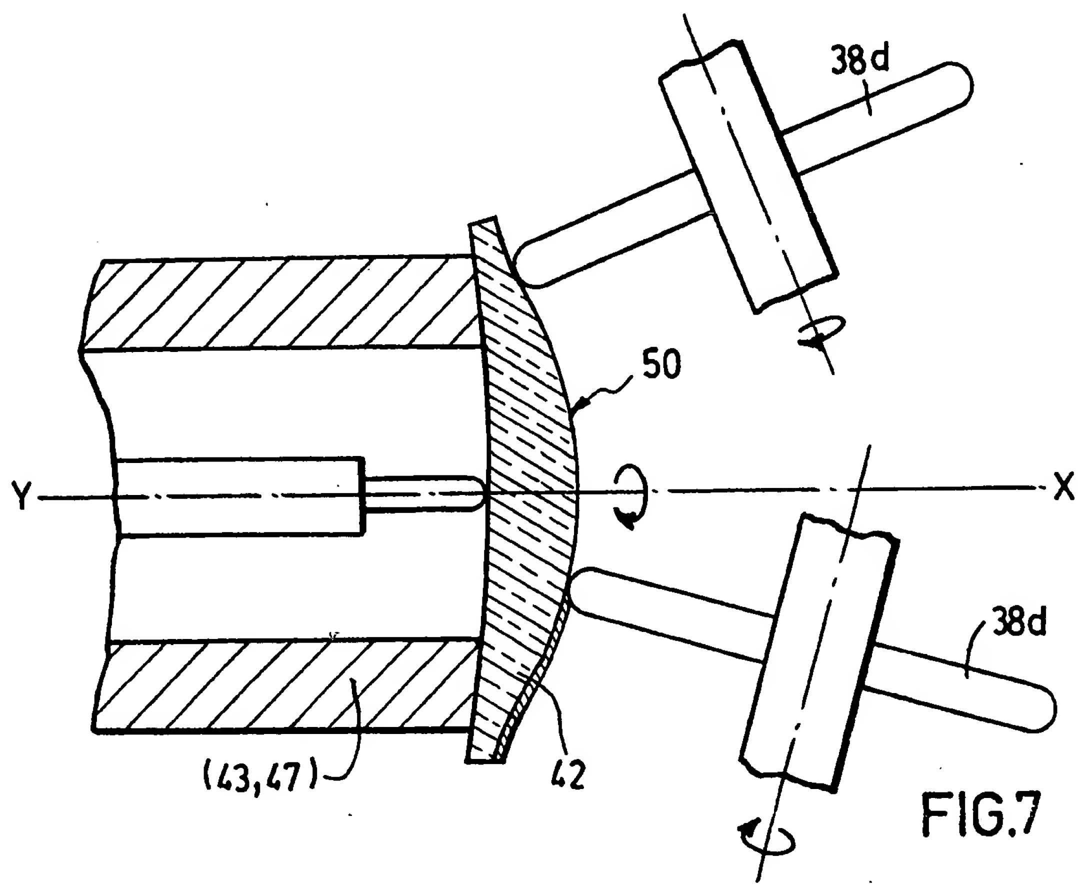

FIG.7

SPECIFICATION

Machin for grinding r machining curved surfaces

Background of the invention

The invention concerns a machine destined for machining curved surfaces, in particular aspheric concave or convex toric rotational surfaces on a part made of a material adapted for this use and such as organic or inorganic glasses, with the use of a cutting tool such as a cup wheel having an abrasive edge or a spherical grinding wheel.

Description of the prior art

Numerous machines of this type have already been produced, including automated or semi-automated versions among those produced, one of the most remarkable, as described in French patent 2,204,987 foresees an arrangement of the lens blank on a support along a vertical axis that coincides with the optical axis of the lens to be machined and a rotating tool, the spindle of which is vertically disposed opposite the part. During machining, this spindle conducts a swinging movement pivoting about an axis passing through the cup of the grinding wheel. The part support is subjected to a double movement along two orthogonal directions situated in a plane perpendicular to the axis of swing of the grinding wheel.

This disposition of the machine to grind the toric surfaces of the optical glasses presents, besides undeniable advantages of compactness and reliability, various drawbacks in modern exploitation conditions of grinding machines, especially as concerns speed and precision of machining. When changing the grinding wheel it is necessary to adjust the spindle of the grinding wheel holder in order to place the axis of swing on the cup of the new grinding machine and such an adjustment is very delicate to carry out.

In order to carry out the machining of the surfaces of highly curved lenses, it is necessary to turn up the lens by 180° during machining since the spindle the grinding wheel holder abuts on the edge of the glass in the case of machining the concave surfaces when the cup of the grinding wheel abuts on the glass bearing chuck in the case of machining convex surfaces.

Furthermore, this machine requires a reverse movement (rise then fall) of the guiding elements, thus provoking additional mechanical clearances that prejudice the precision. A well known default of machines for grinding the surfaces of lenses resides in the fact that they are not provided with automatic means for loading and unloading the parts and blanks which alone permit c nsiderable machining utput. Furthermor , the arrangements of existing machining machines leads the particles rem v d by working and of an abrasiv natur to fall out onto piloting equipment that is both fragile and sensitive to abrasion.

One of the aims of the present invention is precisely to overcome these difficulties and defaults of existing machines, especially in the absence of means allowing the l ading and/or unl ading of blanks and parts during machining, while preserving the qualities of reliability and compactness of known of the same type.

Summary of the invention

With this in mind, in the machine for machining the curved surfaces on an element, particularly, the surfaces of optical lenses or moulds for lenses, of the type comprising, in a base, a first support of a rotating cutting tool that presents a cutting edge destined to enter into contact with the curved surface to be machined, on an element fixed with respect to the base, at least during machining, according to the invention, the spindle of the cutting tool is rigidly fixed to a second support that, during machining, is adapted to be driven by a numerical or digital control system (CNC) rotating about an axis of rotation perpendicular to the axis of rotation of the cutting tool, the second support being itself borne by a third support that, during machining, is adapted to be displaced by numerical control (CNC) along two axes with are orthogonal between them and relative to the axis of rotation of the second support in order to continuously position this axis of rotation of the second cupport along orthogonal coordinates and to cause the curved surface of the fixed part to be generated by the cutting edge of the rotating tool which is simultaneously moved in numerical control in several orthogonal and/or circular directions, and according to an important characteristic of the present invention the blank or part to be machined, such as a glass block, is borne by a head of a rotating support of the revolver-type having several fixed and successive working positions and one of the heads of which is in a first position corresponding to the horizontal axis of the part in the machining position, whereas at least one other head is in a second position corresponding to a loading position, and/or checking position and/or unloading position of the blanks or parts to be machined or already machined.

The principal axis of the cutting tool and that of the surface of the lens during machining are disposed on a substantially horizontal single plane in such a way as to allow during machining an easy expelling of the abrasive particles of the cutting tool and/or of the material of the part to be machined outside the spindle cutting tool holde and ensure a good stiffness to the cutting tool spindle. The third support is protected from the abrasive particles of the cutting tool and/or the material of the part to be worked by a housing having telescopic elements held together and adapted to channel the cooling liquid of the cutting tool and abrasive particles that it brings down outside the zone of orientation and rotation mechanisms of the second support.

As a variant, the rotativ support is mounted on a axis int gral with the bas and supporting geometric checking means f the curved surface to b machined. The checking position comprises ge m t-ric checking means that are, preferably, optical and/ r opto-electronic means directed on the machined surface and electrically and/or electronically coupled to control means of the displacements of the second and third supports. Geometric checking m ans can be pointed n th surface f the

machined on the surface of the machined part that is borne by one of the heads of the rotativ support brought into control position. According to one more complex embodiment of the invention, when control means detect a flaw on the surface after machining of the part, remachining means actuate a further passage of the part in machining position.

The part to be machined can be fixed in a protruding position on one of the heads of the rotative support using unilateral fixation means such as a vacuum cup coupled to a marking follower of its axial position.

According to a very automated embodiment of the invention the axis of the rotative support integral with the base or the spindle of the cutting tool is equipped with checking means of the geometry of the cutting tool such as a grinding wheel and adapted to actuate a rectification phase of the outline of the cutting tool when this outline appears damaged. Checking means of the geometry of the cutting tool are coupled to numerical control means (CNC) of the second and third supports in order to provoke a correction of the path of the cutting edge of the tool in function of the wear of said edge.

Brief description of the drawing

Other aims, advantages and characteristics of the invention will become evident through reading the description of an embodiment of a machine according to the invention for machining lenses for spectacles, given by way of non-limitative example, and with reference to the annexed drawings in which:

Figure 1 is a cross-section of the assembly of the machine according to the invention for machining the toric surfaces of optical lenses;

Figure 2 is a view from above on a larger scale and with the superior hood raised of the centre of the machine of Figure 1;

Figure 3 is a cross-section along plane III of Figure 1 of the rotation mechanism of the machine table this mechanism being represented on a larger scale;

Figures 4 and *5* represent a cross-section seen from above of the different positions of the grinding wheel of the machine during machining of a concave surface and, respectively, of a convex surface of optical lens;

Figure 6 represents similarly a cross-section views from above of two theoretical limit positions of the grinding wheel of the machine during machining of a concave surface of a lens having a small radius of curvature;

Figure 7 represents a partial cross-section seen from above of a machining pass of a revolution aspherical surface using the machine according to the invention.

Description of the preferred embodiments

The machine for machining toric surfaces according t the invention comprises a rigid housing constituted by a base 1 on which are assembled mountings 2 and 3 that laterally support sealing plates 4 and 5. Base 1 mounted itself on a pedestal placed on the ground, sustains supports 6 and 7 of the two transversal guiding axes 8 and 9 f a base support 10 liabl to be displaced transversally by the intermediary of bearings 11 and 12 and under the action f a translati n screw 13 screwed in a nut (not represented) integral with support 10 and driven in rotation by the intermediary of a shaft or a chain 14 coupled to a reversible electrically driven motor 15 controlled by a numerical or digital control system linked up to a computer or a calculating and piloting center (CNC) of the machine.

Base mounting 10 supports, through bearings, grinding bars 16 on which is slidingly mounted by bearings 17, only one of which is shown, an orientable support (or third support) 18 which is relatively rigid. Support 18 can be displaced longitudinally on bars 16 under the action of a screw 19 screwed in a tubular nut 20 and adapted to be driven in rotation by the intermediary of a electric motor 21 for longitudinal translation to which it is coupled by a chain or an indented belt 22. As with motor 15, motor 21 is reversible and controlled by a numerical or digital control system connected to the computing and piloting center of the machine.

Orientable support 18 contains a large section rotation shaft 23 the axis of which is represented in the cross-section of Figure 1.

This shaft 23 is guided by larger roller bearings 24 and bears the working table 25 of the machine that constitutes a second support and is extended by edge sealing plates 26 and 27 fitted into corresponding edges 28 and 29 of the other sealing plates 30 and 31 attached with orientable support 18. In order to complete the sealing of the mechanisms borne by support 18 with respect to the cutting liquid supplied by a pump in the machining zone, edges 32 and 33 of plates 30 and 31 telescopically interlock on respective edges of sheets 4 and 5. Working table 25 is extended by a deeply grooved spindle support 34 and which bears rigid spindle 35 can receive various types of cup grinding wheels 38 fitted with abrasive edges having diameters adapted to radii R of the surfaces of the lenses to be machined.

According to the invention spindle 35 and its driving motor 36 are rigidly fixed on support 34, itself integral with working table 25 liable to turn under the action of a screw 39 acting on a toothed crown 39*a* integral with shaft 23. Figure 3 shows screw 39 connected, by a chain or idented belt 40, to a reversible electrically driven motor 41 which is flanged on orientable support 18.

According to another important aspect of the invention, the blank to be machined made, in the embodiment described, of a glass block 42 is disposed with its principal optical axis in a horizontal plane substantially coinciding with the horizontal plane of the axis of spindle 35. The blank to be machined 42 is borne by one 43 of the multiposition heads of a revolving rotative support 44 mounted on a guiding axis 45 fixed t mounting 2 by a support flange 46.

A station 48 for the automatic loading and unloading of the blanks and parts to be machined is foreseen with respect to head 47 in the position shown in Figur 1. A geometric checking station 49 of the machined surfaces is also fores en with respect to head 47 in its represented position. G ometric checking means can be constituted by

ptical and/or opto-electronic means such as a ph t -el ctric cell coupled to one or several sensors connected to the computing and piloting center f the numerical or digital control of the machine. Furthermore, spindle 35 or an ther part of the machine, integral with the spindle, can be equipped with check means 51 of the geometry of the active part of the grinding wheel and particularly of the diameter of its abrasive edge surface.

The blank 42 to be machined is fixed in a protruding position on head 43 by any means but, preferably, by a vacuum cup 52 and the position and/or presence of the part on the bearing face 53 of head 43 can be marked by a follower 54 mechanically associated where necessary, to a cam surface (not shown) of the guiding axis 45.

According to one important characteristic of the invention, the axis of rotation 55 of shaft 23 (and thus of the working table 25 of spindle 35 and grinding wheel 38) is perpendicular to the axis of rotation of grinding wheel 38 and is preferably situated before grinding wheel 38 with respect to spindle 35, such as represented, whatever the surface of the lens generated, concave or convex, the axis of rotation 55 being displaced during each machining pass with respect to the curved surface to be shaped 50.

Figure 1 shows an exploded cross-section of various types of cup grinding wheel having different diameters (38*a*, 38*b*, 38*c*), used for generation lens surfaces according to the minimum and maximum radii of the toric surfaces to be machined.

In order to fully explain the operating of the machine for machining lens surfaces shown in Figures 1 to 3, reference is made, first of all, to Figures 4 and 6 that represent on a large scale different relative positions between the active surface of a grinding wheel 38 and the surface of lens 50 to be machined. Figure 4 represents in the horizontal plane of the axis of spindle 35 three successive positions of a grinding wheel 38*b* of average diameter during grinding of the concave surface 50 of a lens 42.

The abrasive edge surface 56 of grinding wheel 38*b* contacts concave surface 50, by a curved tangent line shown in projection in Figure 4, by a straight line 57. This curved tangent line must remain identical during maching in order to form toric surface 50 and for that angle β which forms the axis of the grinding wheel with the perpendicular to surface 50 at the machining point must be constant throughout the machining pass. This constancy of angle β can be easily respected by numerical or digital control of rotation of shaft 23.

Figure 5 represents machining convex face 50 of a lens having an opening α and a greater external radius R, by a grinding wheel 38*b* of average diameter. It can be noted that the glass of the lens engages inside th belt of the grinding wheel with ut entering into contact with the internal face of this belt. The machining of convex surface 50 can thus be produced in a single pass and the surface of belt 56 surr unds curved tangent line 57 through the intermediary of th belt inside maintained at a fixed radius *r*.

Figur 6 shows two p sitions of grinding wheel during machining of the internal concave surface 50 of a lens 42 having a greater curvature radius R. The surface of belt or cup 56 of the grinding wheel 38*b* surrounds surface 50 on a very curved long tangent line and grinding wheel spindle h lder contacts the upper edge of lens 42 if the relative displacement of grinding machine 38*b* is continued towards the bottom of the drawing. It is thus necessary to carry out machining of convex surface 50 in two separate passes that join up, preferably, at the centre of surface 50 while still retaining angle of inclination β of the axis the grinding wheel with the normal to surface 50 at the machining point, so as to preserve a constantly curved tangent line.

Figure 7 shows diagrammatically a machining pass of a convex aspherical rotation surface. In this variant of utilising the machine according to the invention, the blank AZ to be machined, fixed at the end of one of the heads, (43, 47) is rotated about its optical axis YX. Corresponding driving means are within the capability of the man skilled in the art and are not represented in detail on this drawing. Machining such a surface can be carried out by means of cup type grinding wheels (38*a*, 38*b*, 38*c*) or, furthermore, by means of a spherical cup wheel grinder 38d such as represented. For a spherical cup grinding wheel 38d, the axis of the grinding wheel holder spindle will be horizontal and perpendicular to the plane of Figure 1, at rest position. Figure 7 shows by way of example two positions of grinding wheel 38d for which the axis of rotation of the grinding wheel is perpendicular to the normal at the generator of the surface at the given point.

In order to carry out a machining operation of a toric surface on the machine according to the invention, operator 48 disposes a crude glass part 59 to be machined on the sealing of head support 47 and, after evacuating the air of the corresponding vacuum chamber 52, crude glass part 59 is rigidly held on head 47. After completion of machining the part 42 to be machined, rotative support 44 turns and brings machined part 42 to the unloading and checking position and the rough part 59 into machining position.

Machining table 25 has been drawn back into the position shown in Figure 1. Upon actuation of the machining cycle, grinding wheel 38 is already driven in rotation and longitudinally translation motor 21 is energized through the computing centre of digital or numerical control, in the forward direction of grinding wheel stroke 38 towards the surface to be machined 50.

Rotation driven motor 41 is also actuated in order to cause machining table 25 to turn and to set the axis of spindle 35 in such a way as to respect cutting angle β of the surfac 50 through the belt surface 56 of grinding wheel 38. Further, motor 15 is energized through digital or numerical contr l system so as to bring the machining edge of the surface of belt 56 of the grinding wheel to the edge of surface 50 to be machined on part 42, this cutting edge being, for example, indicated by the phot -electric cell of geometric checking means 51.

Once grinding wheel 38 is positioned, the digital r numerical control syst m of th machine actuates

successive machining passes of the surface of belt 56 of grinding whe l 38 according to curved tangent line 57 represented on Figures 4 and 5 by simultaneous rotation of motors 15, 21, and 41, coordinated by the digital control system, until obtention of the geometrical dimension required for surface 50. Machining table 25 is thereafter brought back to the position shown in Figure 1 in order to allow the rotation of revolver support 44 and the continuation of the machining process of another rough part 59.

The machine for shaping the surfaces of lenses according to the invention allows to ensure a larger machining output and greater reliability than machines known per se, principally due to revolver support 44, to the protection of its internal mechanisms by a housing of telescopic elements 4, 5, 30, 31, and greater rigidity of its components.

The machining of lens surface is carried out by successive passes executed continuously without interruption until the obtention of the final and definitive dimension Figure, even for lens surfaces having a high curvature for which the taking up again by changing the attack side of the grinding wheel takes place automatically under the control of the digital control.

Machining of surface 50 can be carried out in two passages after a precise dimensional checking opposite a control post 49. The finition pass can be carried out, for example, after trimining of the surface of another part 42. Machining an aspherical rotation surface is carried out according to the same process as that for machining a torical surface.

Of course, the present invention is in no way limited to the embodiments described and represented herein-above and it can be adapted to numerous variants available to the man skilled in the art, without departing from the spirit and scope of the invention.

Thus, the mechanical control for displacement by electric motors according to the axes of orientation and rotation of machining table 2S could be realized by using any equivalent means such as hydraulic jack, or other, coupled and coordinated by a digital control system.

CLAIMS

1. Machine for machining the curved surfaces on an element, particularly, the surfaces of optical lenses or moulds for lenses, of the type comprising, in a base, a first support of a rotating cutting tool that presents a cutting edge destined to enter into contact with the curved surface to be machined, on an element fixed with respect to the base, at least during machining, wherein the spindle of the cutting tool is rigidly fixed to a second support that, during machining, is adapted to b driven by a numerical or digital contr l system (CNC) rotating about an axis of rotation perpendicular to th axis of rotation of the cutting tool, the second support being itself borne by a third support that, during machining, is adapted to be displaced by numerical control (CNC) along two axes which ar rthogonal between th m and relative to the axis f rotation order to c ntinously position this axis of rotati n of the second supp rt along orthogonal coordinates and to cause the curved surface of the fixed part to be generated by the cutting edge of the rotating tool which is simultaneously moved in numerical control in several orthogonal and/or circular directions, wherein the blank or part to be machined, such as a glass block, is borne by a head of a rotating support of the revolver-type having several fixed and successive working positions and one of the heads of which is in a first position corresponding to the horizontal axis of the part in the machining position, whereas at least one other head is in a second position corresponding to a loading position, and/or checking position and/or unloading position of the blanks or parts to be machined or already machined.

2. Machine according to claim 1, wherein the principal axis of the cutting tool and that of the surface of the lens during machining are disposed on a substantially horizontal single plane in such a way as to allow during machining an easy expelling of the abrasive particles of the cutting tool and/or of the material of the part to be machined outside the spindle cutting tool holder and ensure a good stiffness to the cutting tool spindle.

3. Machine according to one of claims 1 or 2, wherein the third support is protected from the abrasive particles of the cutting tool and/or the material of the part to be worked by a housing having telescopic elements held together and adapted to channel the cooling liquid of the cutting tool and abrasive particles that it brings down outside the zone of orientation and rotation mechanisms of the second support.

4. Machine according to one of claims 1 to 3, wherein the rotative support is mounted on a axis integral with the base and supporting geometric checking means of the curved surface to be machined.

5. Machine according to claim 4, wherein the geometric checking means are optical and/or optoelectronic means directed on the machined surface and electrically and/or electronically coupled to control means of the displacements of the second and third supports.

6. Machine according to claim 5, wherein the geometric checking means are pointed on the surface of the machined part that is borne by one of the heads of the rotative support brought into control position.

7. Machine according to claim 6, wherein when control means detect a flaw on the surface after machining of the part, remachining means actuate a further passage of the part in machining position.

8. Machine according to one of claims 1 to 7, wherein the part to be machined is fixed in a protruding p sition on one of the heads of the rotative support using unilateral fixation means such as a vacuum cup, wherein the fixation means is coupled to a marking follower of its axial position.

9. Machine according to one of claims 1 to 8, wherein the spindle of the cutting tool is equipped with checking means of the geometry of the cutting tool such as a grinding wheel and adapted t actuate a rectificati n phas of the outlin of the cutting tool when this outline appears damaged.

10. Machine according to claim 9, wherein the checking means of the geometry of the cutting tool are coupled to numerical control means (CNC) of the second and third supports in order to provoke a correction of the path of the cutting edge of the tool in function of the wear of said edge.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1984.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.